Comparison of diffusion tensor imaging and magnetization transfer imaging in the detection of brain trauma

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Introduction

The sensitivity and specificity of MRI in detecting diffuse axonal injury are critical issues in studying therapeutic interventions for traumatic brain jury (TBI). Diffusion tensor imaging (DTI) and magnetization transfer imaging (MTI) are capable of detecting white matter abnormalities in TBI[1,2]. Considering the different mechanism of signal detection DTI and MTI together may provide useful complementary information of the tissue's structural integrity beyond any single method of them. In the current study, we show that the magnetic transfer ratio (MTR) is more sensitive in detecting white matter membrane abnormality after the linear acceleration closed head (LACH) model of diffuse TBI.

Materials and Methods

LACH TBI and MRI

Diffuse axonal injury was generated on five female 8-week-old Wistar rats by 2-m height LACH TBI without inducing focal contusions. Animals were imaged prior to TBI (baseline), and at 1- and 8-days post-inury (DPI). MRI data were acquired in vivo using a Dolty quadrature coil on a Bruker 7T spectrometer. 3D multiple gradient echo (MGE) and time-of-flight MR angiography (MRA) were first performed to examine hemorrhage, edema, and vasculature alteration after TBI. Parameters for the MRA: TR 30ms, TE 3.2 ms, FOV 1.4 × 2.56 × 1.8 (cm), voxel size 90 (μm, isotropic); NEX 3. Scan time was 30 min. For MGE: TR 60ms, TE 3.17 ms, Echo spacing: 3.25ms, FOV 3.5 × 2.56 × 1.4 (cm), voxel size 200 (μm, isotropic); NEX 2. Scan time was 10 min. DTI was acquired using 3D spin echo EPI: TR 700ms, TE 37 ms; segment 4, Δ 15 ms; δ 5 ms; *b*-value 0 and 800 s/mm^2 with 15 encoding directions. FOV and the voxel size of DTI are identical with MGE. Scan time was 50 min. MTI was acquired by 2D spin echo sequence with (M_S) and without (M_0) magnetic transfer (MT) preparation pulses added before excitation. Parameters for MT pulse were: offset 6kHz, amplitude 4μT, duration 1ms, pulse number 20, resolution 200 × 200 × 500 (μm).

Data Analysis

T2* maps were generated by fitting the T2* relaxation decay using 14 echoes MGE data. Maximum intensity projection were used for producing 3D MRA. Fractional anisotropy (FA), axial diffusivity (AD), and radial diffusivity (RD) were derived for DTI indices of white matter injury. MTR map were calculated by ($1-M_S/M_0$). Corpus callosum was the region of interest to inspect white matter integrity. Data are reported as mean ± standard deviation. Two way repeated measures ANOVA was used for significance test. All imaging data were processed by in house Matlab scripts.

Results

Serial T2* maps and MRA show clear edema and dilated vessels in the cerebrum confirming the brain injury generated by LACH TBI (Fig. 1). The DTI and MTI parameter maps of white matter injury are shown in Fig. 2. Comparing to the DTI parameters, the MTR maps show a clear alteration of contrast in images from baseline to 8DPI. The quantification of these parameters from 5 animals is disclosed in Fig. 3. Both AD and MTR show significant differences when detecting changes in white matter integrity in the corpus callosum. MTR appears superior in sensitivity when reflecting different status of white matter injury in the TBI time course.

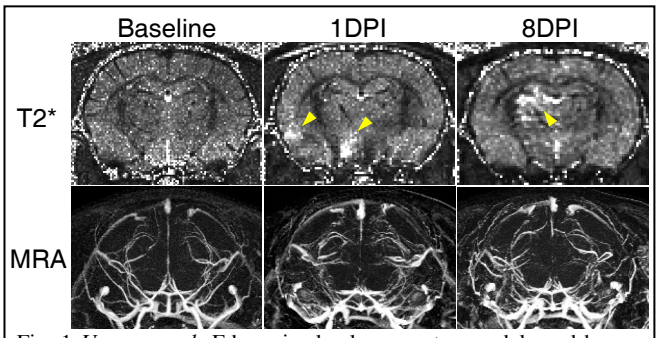

Fig. 1 *Upper panel:* Edema is clearly seen at amygdala and hypothalamus (arrows) in the T2* map of 1DPI. At 8DPI, extensive edema appears in hippocampus (arrow). Lesions are found near bregma -2.52mm. *Lower panel:* MRA shows that the cerebral vasculature becomes intensively dilated and aberrant after LACH TBI.

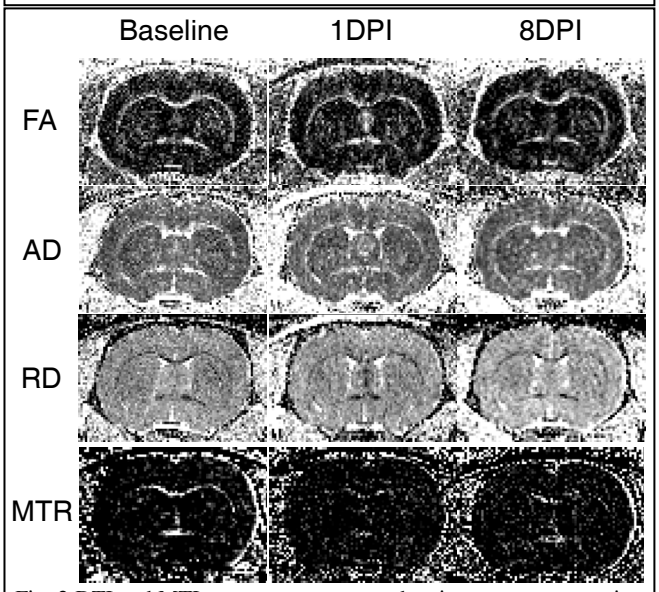

Fig. 2 DTI and MTI parameter maps are showing at a representative slice near bregma -0.12mm. The contrast of MTR maps appears superior in reflecting the white matter alteration along the LACH injury time course.

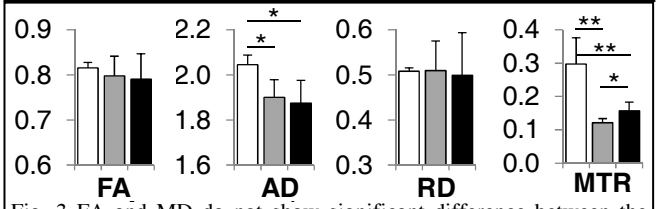

Fig. 3 FA and MD do not show significant difference between the baseline (□), 1DPI (▨), to 8DPI (■). Comparing to the baseline, AD significantly decrease in both 1DPI and 8DPI, while the changes of MTR have higher significance. Scales of AD and RD are with unit of μm^2/ms. *p < 0.05, **p < 0.02, ***p < 0.01, N=5.

Discussions and Conclusions

Our data show that AD and MTR are both sensitive in reflecting white matter injury in LACH TBI. While AD is suggested to reflect axonal integrity[1], the MTR has been used to correlate with both myelin loss and axonal destruction[2]. More precisely, the temporary increase of membrane permeability, of both axon and myelin, and the blood-brain barrier may all contribute to increased sensitivity of MTR to reflect white matter injury[3]. Further work is underway to provide histological evidence of the findings.

References 1. Bennett et al., Neurosci Lett. 2012 4;513; (2):160-5. **2.** Bagley et al., JMRI, 2000; 11(1): 1–8; **3.** Giza et al., J Athl Train. 2001; 36(3): 228–235.